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(54) OFDM transmission/reception apparatus with selection of the optimal guard interval length

(57) The subtractor of the reception system calculates the channel quality using an optimal guard interval length detection signal inserted into one carrier by the transmission system, then the optimal guard interval length detector calculates the minimum guard interval length necessary to eliminate delayed signals using this calculated channel quality, inserts the control signal indicating this guard interval length into one carrier and the reception system sets the guard interval length using this control signal.

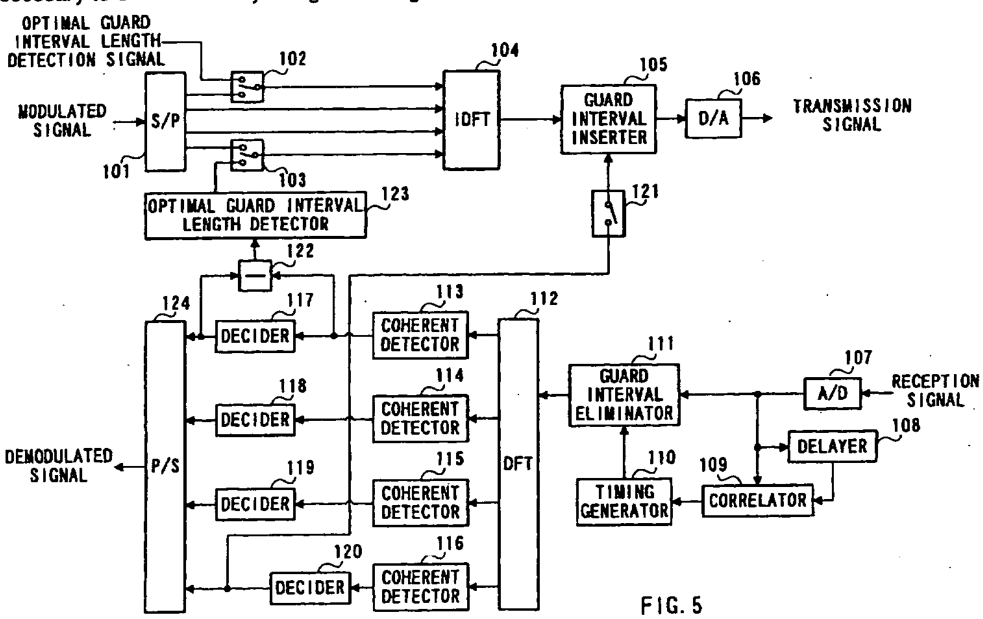


FIG. 5

EP 1 014 639 A2

and exp (jΘ(nT)) is a phase variation due to fading.

[0016] F (nT), which represents a variation due to fading, is expressed as follows:

$$\begin{aligned} F(nT) &= In(nT) \cdot P(nT) \\ &= \{P(nT) \cdot A(nT) \cdot \exp(j\Theta(nT))\} \cdot P(nT) \\ &= P(nT)^2 \cdot A(nT) \cdot \exp(j\Theta(nT)) \qquad -① \end{aligned}$$

Here, in a modulation system such as a QPSK modulation system in which the amplitude is constant and only the phase contains information, $P(nT)^2 = 1$. Therefore, expression ① is expressed as follows:

$$F(nT) = A(nT) \cdot \exp(j\Theta(nT))$$

[0017] Then, digital multiplier 41 obtains signal F (nT) that represents a variation due to fading by multiplying DFT-processed input signal (baseband signal) In (nT) by pilot symbol P (nT) in a pilot symbol interval.

[0018] Then, conjugate complex number generator 43 generates a conjugate complex number about F (nT), a signal representing a variation due to fading. In this way, conjugate complex number $F(nT)^*$ of F (nT) signal expressing a variation due to fading is obtained. Conjugate complex number generator 43 inverts the polarity of the Q component of the input signal and generates a conjugate complex number. Therefore, conjugate complex number $F(nT)^*$ is expressed in the following expression:

$$F(nT)^* = A(nT) \cdot \exp(-j\Theta(nT))$$

[0019] Then, digital multiplier 42 multiplies the DFT-processed input signal (baseband signal) by the conjugate complex number of the signal representing a variation due to fading. In this way, a coherent detected signal is obtained.

[0020] Here, suppose the fading variation is sufficiently slow compared to the interval of pilot symbols and the fading variation is constant between pilot symbols. Based on this supposition, coherent detected signal $D_{out}(nT)$ is expressed in the following expression:

$$\begin{aligned} D_{out}(nT) &= D_{in}(nT) \cdot A(nT) \cdot \exp(j\Theta(nT)) \\ &\qquad \cdot A(nT) \cdot \exp(-j\Theta(nT)) \\ &= D_{in}(nT) \cdot A(nT)^2 \qquad -② \end{aligned}$$

[0021] In expression ②, $A(nT)^2$ is the component with a constant phase and variable amplitude. Therefore, the phase variation of coherent detected signal $D_{out}(nT)$ is only dependent on $D_{in}(nT)$. Therefore, the phase of the reception signal is demodulated by digital multiplier 42 multiplying the DFT-processed input signal (baseband signal) by a conjugate complex number of the signal indicating a variation due to fading. The QPSK modulation system is a modulation system with a constant amplitude and variable phase. Therefore, the OFDM transmission/reception apparatus performs coherent detection by demodulating the phase of the reception signal.

[0022] Furthermore, the OFDM transmission/reception apparatus can also eliminate any phase difference between transmission and reception carriers and phase variation by frequency offset as well as fading variation.

[0023] In a modulation system such as a 16QAM modulation system with a variable phase and variable amplitude, the OFDM transmission/reception apparatus detects a fading variation by dividing an input signal in the pilot symbol interval by a pilot symbol. The OFDM transmission/reception apparatus then performs coherent detection by dividing the input signal by a signal indicating a fading variation.

[0024] The OFDM transmission/reception apparatus can also use a delay detection system as the demodulation system.

[0025] The coherent signals detected by coherent detectors 21 to 24 are judged by Deciders 25 to 28. After judgment, the 4 signals are converted to a single signal by P/S converter 29. In this way, a demodulated signal is obtained.

[0026] As shown above, the conventional OFDM transmission/reception apparatus adds a signal with the same

OFDM transmission/reception apparatus according to Embodiment 8 of the present invention;

FIG.18 is a block diagram showing an outlined configuration of an optimal guard interval length detector of an OFDM transmission/reception apparatus according to Embodiment 9 of the present invention;

FIG.19 is a block diagram showing an outlined configuration of an OFDM transmission/reception apparatus according to Embodiment 10 of the present invention;

FIG.20 is a block diagram showing an outlined configuration of an OFDM transmission/reception apparatus according to Embodiment 11 of the present invention;

FIG.21 is a block diagram showing an outlined configuration of an OFDM transmission/reception apparatus according to Embodiment 12 of the present invention;

FIG.22 is a block diagram showing an outlined configuration of an OFDM transmission/reception apparatus according to Embodiment 13 of the present invention;

FIG.23 is a block diagram showing an outlined configuration of a UW detector of the OFDM transmission/reception apparatus according to Embodiment 13 of the present invention;

FIG.24 is a block diagram showing an outlined configuration of a UW detector of an OFDM transmission/reception apparatus according to Embodiment 14 of the present invention;

FIG.25 is a block diagram showing an outlined configuration of an OFDM transmission/reception apparatus according to Embodiment 15 of the present invention;

FIG.26 is a block diagram showing an outlined configuration of a UW detector of the OFDM transmission/reception apparatus according to Embodiment 15 of the present invention;

FIG.27 is a block diagram showing an outlined configuration of an OFDM transmission/reception apparatus according to Embodiment 16 of the present invention;

FIG.28 is a block diagram showing an outlined configuration of a UW detector of the OFDM transmission/reception apparatus according to Embodiment 16 of the present invention;

FIG.29 is a block diagram showing an outlined configuration of a UW detector of an OFDM transmission/reception apparatus according to Embodiment 17 of the present invention;

FIG.30 is a block diagram showing an outlined configuration of an OFDM transmission/reception apparatus according to Embodiment 18 of the present invention;

FIG.31 is a timing chart showing an example of the step of a guard interval inserter of the OFDM transmission/reception apparatus according to Embodiment 18 of the present invention adding a guard interval; and

FIG.32 is a timing chart showing an example of the step of a guard interval eliminator of the OFDM transmission/reception apparatus according to Embodiment 18 of the present invention eliminating a guard interval.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0030] With reference now to the attached drawings, the embodiments of the present invention are explained in detail below.

(Embodiment 1)

[0031] The OFDM transmission/reception apparatus according to Embodiment 1 of the present invention is explained using FIG. 5. FIG.5 is a block diagram showing an outlined configuration of the OFDM transmission/reception apparatus according to Embodiment 1 of the present invention.

[0032] S/P converter 101 converts a serial input signal to a plurality of parallel signals. Switches 102 and 103 switch between two input signals and outputs either of the two. IDFT circuit 104 performs IDFT processing on the input signals. Guard interval inserter 105 inserts a guard interval into the input signal for every valid symbol. D/A converter 106 performs D/A conversion on the signal with a guard interval inserted. In this way, a transmission signal is obtained.

[0033] A/D converter 107 performs A/D conversion on a reception signal. Delayer 108 delays the input signal by a valid symbol length. Correlator 109 despreads the input signal. Timing generator 110 detects the timing of the reception signal at which the correlation value becomes largest. Guard interval eliminator 111 eliminates the guard interval inserted for every valid symbol. DFT circuit 112 performs DFT processing on the input signal.

[0034] Coherent detectors 113 to 116 perform coherent detection on the input signal. Deciders 117 to 120 judge the input signals. Switch 121 selects a control signal to select the optimal guard length from the signal output from Decider 120. Subtractor 122 performs a subtraction between the signal input to Decider 117 and the signal output from Decider 117. Optimal guard interval length detector 123 generates a control signal to select the optimal guard interval length from the output of subtractor 122. P/S converter 124 converts a plurality of parallel input signals to a serial signal.

[0035] Then, the operation of the OFDM transmission/reception apparatus according to the present embodiment is explained. Here, a case where the number of carriers is 4 is explained, for example.

[0036] First, the operation of the transmission system is explained. The OFDM transmission/reception apparatus of

signals using the decision error of each symbol of the optimal guard interval length detection signal. Then, the OFDM transmission/reception apparatus of the present embodiment can decide the guard interval length by calculating a logical product of the selected window signal (output of switch 204) and a valid symbol.

[0049] Logical product calculator 205 calculates the logical product of the output of switch 204 and the output of IDFT circuit 104. In this way, the OFDM transmission/reception apparatus of the present embodiment can extract part of a valid symbol, and thus can generate a guard interval.

[0050] Then, P/S converter 206 performs P/S conversion of the guard interval signal, which is the output of logical product calculator 205, and the output signal of IDFT circuit 104. In this way, an IDFT signal with a guard interval inserted is obtained.

[0051] Here, the step of guard interval inserter 105 generating guard intervals is explained using FIG.7. FIG.7 is a timing chart showing an example of the step of the guard interval inserter of the OFDM transmission/reception apparatus of the present embodiment generating guard intervals.

[0052] The signal shown at A represents a valid symbol. Likewise, B represents window signal 1; C, window signal 2; D, window signal 3; E, window signal 4; F, guard interval signal; G, valid signal delayed by 1 symbol; and H, IDFT signal after addition of a guard interval.

[0053] The OFDM transmission/reception apparatus of the present embodiment selects one of window signals with different high-level interval lengths and finds the logical product of the window signal and the valid symbol. In this way, the OFDM transmission/reception apparatus of the present embodiment can set the same number of guard interval lengths as the number of window signals.

[0054] For example, the guard interval signal shown at F is generated as follows. That is, the OFDM transmission/reception apparatus of the present embodiment calculates the logical product of the valid symbol shown at A and window signal 3 shown at D to extract the symbol with the same length as the high-level interval of window signal 3 shown at D from the last part of valid symbol A. In this way, the guard interval signal shown at F is generated.

[0055] As shown above, the OFDM transmission/reception apparatus of the present embodiment selects a window signal with a different high-level interval length every time an optimal guard interval length detection signal inserted into a transmission signal is received. Then, the OFDM transmission/reception apparatus of the present embodiment calculates the logical product of the selected window signal and valid symbol to generate a guard interval according to the channel quality. In this way, the OFDM transmission/reception apparatus of the present embodiment can expand/contract a guard interval length according to the channel quality.

[0056] Then, the operation of the reception system of the OFDM transmission/reception apparatus of the present embodiment is explained using FIG.5.

[0057] The reception signal input to the reception system is converted to a digital signal by A/D converter 107.

[0058] The OFDM transmission/reception apparatus of the present embodiment calculates a correlation between a pre-DFT signal and the pre-DFT signal delayed by a valid symbol length. The OFDM transmission/reception apparatus of the present embodiment detects the integration interval of DFT by detecting the timing at which the correlation result becomes largest. More specifically, delayer 108 delays the reception signal by the valid symbol length, then correlator 109 calculates a correlation and timing generator 110 detects the timing at which the correlation result becomes largest. Guard interval eliminator 111 eliminates the guard interval from the reception signal according to this detection result.

[0059] The reception signal stripped of the guard interval is DFT-processed by DFT circuit 112. This results in 4 baseband signals, which are carried by 4 carriers. The 4 baseband signals are subjected to coherent detection by coherent detectors 113 to 116, respectively. In this way, coherent detected signals are obtained. Here, a delay detection system can also be used as the demodulation system.

[0060] The coherent detected signals obtained by coherent detectors 113 to 116 are judged by Deciders 117 to 120. The 4 signals judged by Deciders 117 to 120 are converted to a serial signal by P/S converter 124. In this way, a demodulated signal is obtained.

[0061] On the other hand, switch 121 selects only the optimal guard interval length selection control signal from the output signal of Decider 120 and outputs it to guard interval inserter 105.

[0062] Subtractor 122 carries out a subtraction between the signal input to Decider 117 and the signal output from Decider 117 to calculate the decision error. Here, this decision error is determined as the channel quality. Optimal guard interval length detector 123 generates an optimal guard interval length selection control signal using the decision error calculated by subtractor 122, that is, channel quality information.

[0063] Here, the optimal guard interval length detector of the OFDM transmission/reception apparatus of the present embodiment is explained using FIG.8. FIG.8 is a block diagram showing an outlined configuration of the optimal guard interval length detector of the OFDM transmission/reception apparatus of the present embodiment.

[0064] The decision error input to optimal guard interval length detector 123 is selectively output by switch 401 and S/P-converted by S/P converter 402.

[0065] Subtractor 403 calculates a subtraction between the first output of S/P converter 402 and the second output of S/P converter 402. Likewise, subtractor 404 calculates a subtraction between the first output and the third output, and

figuration as that of the OFDM transmission/reception apparatus of Embodiment 1 and inserts symbols for optimal guard interval length detection signals into a plurality of carriers.

[0082] The optimal guard interval length detector of the OFDM transmission/reception apparatus of the present embodiment is explained below using FIG. 10. FIG.10 is a block diagram showing an outlined configuration of the optimal guard interval length detector of the OFDM transmission/reception apparatus of Embodiment 3 of the present invention. The parts with the same configuration as that of Embodiment 1 are assigned the same numbers and their detailed explanations are omitted.

[0083] The transmission system of the OFDM transmission/reception apparatus of the present embodiment has switch 601. With switch 601, an optimal guard interval length detection signal is inserted into not only carrier 1 but also carrier 2.

[0084] Furthermore, the reception system of the OFDM transmission/reception apparatus of the present embodiment also has subtractor 602 and Averager 603. Subtractor 602 calculates the decision error of carrier 2. Averager 603 calculates the average of decision errors of carrier 1 and carrier 2. Averager 603 outputs the average value of the decision errors to optimal guard interval length detector 123.

[0085] As shown above, the OFDM transmission/reception apparatus of the present embodiment inserts an optimal guard interval length detection signal into a plurality of carriers and generates an optimal guard interval length selection control signal using the average value of decision errors. This allows the OFDM transmission/reception apparatus of the present embodiment to achieve higher accuracy of optimal guard interval length selection control signal than that of the OFDM transmission/reception apparatuses of Embodiments 1 and 2.

(Embodiment 4)

[0086] The OFDM transmission/reception apparatus of Embodiment 4 of the present invention has the same configuration as that of the OFDM transmission/reception apparatus of Embodiment 3, but does not average optimal guard interval length detection signals before they are input to the optimal guard interval length detector and performs a logical product calculation on the optimal guard interval length detection signals using the optimal guard interval length detector.

[0087] The optimal guard interval length detector of the OFDM transmission/reception apparatus of the present embodiment is explained below using FIG. 11 and FIG.12.

FIG.11 is a block diagram showing an outlined configuration of the OFDM transmission/reception apparatus of Embodiment 4 of the present invention. FIG.12 is a block diagram showing an outlined configuration of the optimal guard interval length detector of the OFDM transmission/reception apparatus of Embodiment 4 of the present invention. The parts with the same configuration as that of Embodiments 1 and 3 are assigned the same numbers and their detailed explanations are omitted.

[0088] As shown in FIG.11, the OFDM transmission/reception apparatus of the present embodiment does not average the decision errors of carrier 1 and carrier 2, and inputs the decision errors of carrier 1 and carrier 2 to optimal guard interval length detector 701.

[0089] Then, as shown in FIG.12, logical product calculators 801 to 803 perform a logical product calculation on the outputs of Deciders 409 to 411 for carrier 1 and the outputs of Deciders 409 to 411 for carrier 2.

[0090] As shown above, the OFDM transmission/reception apparatus of the present embodiment can achieve higher accuracy of an optimal guard interval length selection control signal by selecting a guard interval length whose difference between decision errors falls below a threshold as the optimal guard interval length in all carriers into which symbols for optimal guard interval detection have been inserted.

(Embodiment 5)

[0091] The OFDM transmission/reception apparatus of Embodiment 5 of the present invention has the same configuration as that of the OFDM transmission/reception apparatus of Embodiment 3 but does not use carriers whose reception level falls below a threshold to detect the optimal guard interval length.

[0092] The optimal guard interval length detector of the OFDM transmission/reception apparatus of the present embodiment is explained below using FIG.13.

FIG.13 is a block diagram showing an outlined configuration of the OFDM transmission/reception apparatus of Embodiment 5 of the present invention. The parts with the same configuration as that of Embodiments 1 and 3 are assigned the same numbers and their detailed explanations are omitted.

[0093] Square sum calculator 901 calculates the sum of squares of coherent detected signals of carrier 1. Square sum calculator 902 calculates the sum of squares of coherent detected signals of carrier 2.

[0094] Then, subtractor 903 carries out a subtraction between the output of square sum calculator 901 and a threshold and Decider 905 decides which is larger/smaller based on the subtraction result. Subtractor 904 carries out

indicates |Q|>|I|, switch 1103 outputs |Q|. Furthermore, when the output of Decider 1106 indicates |I|>|Q|, switch 1104 outputs |Q|. When the output of Decider 1106 indicates |Q|>|I|, switch 1104 outputs |I|. In short, switch 1103 outputs |I| or |Q|, whichever is greater and switch 1104 outputs |I| or |Q|, whichever is smaller.

[0111] The smaller one of |I| or |Q| output from switch 1104 is shifted by 2 bits and 3 bits by 2-bit shifter 1107 and 3-bit shifter 1108, respectively.

[0112] Since a 1-bit shift reduces the amplitude to half, the amplitude becomes 0.25 times with a 2-bit shift and 0.125 times with a 3-bit shift. Therefore, the amplitude of the output signal of 2-bit shifter 1107 becomes 0.25 times the amplitude of the output signal of switch 1104. The amplitude of the output signal of 3-bit shifter 1108 becomes 0.125 times the amplitude of the output signal of switch 1104.

[0113] Then, adder 1109 adds up the output signal of 2-bit shifter 1107 ($0.25 \times |I|$ or $0.25 \times |Q|$) and the output signal of 3-bit shifter 1108 ($0.125 \times |I|$ or $0.125 \times |Q|$). Therefore, the output signal of adder 1109 becomes $0.375\times |I|$ or $0.375 \times |Q|$.

[0114] Then, adder 1110 adds up the output signal of switch 1103 (|I| or |Q|) and the output signal of adder 1109 ($0.375\times |I|$ or $0.375 \times |Q|$). From this, envelope information Z is obtained from the approximate expression above.

[0115] As shown above, the level detector of the OFDM transmission/reception apparatus of the present embodiment detects the reception level by finding an envelope, and thus it does not perform a multiplication unlike the square sum calculator of Embodiment 5. Therefore, the OFDM transmission/reception apparatus of the present embodiment has a simpler configuration, making it possible to reduce the necessary amount of calculation.

[0116] Moreover, the OFDM transmission/reception apparatus of the present embodiment can further reduce the necessary amount of calculation in calculating an envelope by using an approximate expression only consisting of simple multiplications and additions, which can be implemented by bit shifts on the circuit.

[0117] The present embodiment describes the case where the input signal is a QPSK-modulated signal. However, the above apparatus configuration is also applicable to any other cases where other modulation systems are used so long as the input signal can be separated into the I component and Q component.

(Embodiment 7)

[0118] The OFDM transmission/reception apparatus of Embodiment 7 of the present invention has the same configuration as that of the OFDM transmission/reception apparatus of Embodiment 1 and uses a known symbol as the optimal guard interval length detection signal.

[0119] The OFDM transmission/reception apparatus of the present embodiment is explained below using FIG.16. FIG.16 is a block diagram showing an outlined configuration of the OFDM transmission/reception apparatus of Embodiment 7 of the present invention. The parts with the same configuration as that of Embodiment 1 are assigned the same numbers and their detailed explanations are omitted.

[0120] As shown in FIG.16, the OFDM transmission/reception apparatus of the present embodiment uses a known symbol as the optimal guard interval length detection signal. Subtractor 1201 performs a subtraction between the carrier 1 signal prior to its input to Decider 117 and a known symbol and outputs the difference between these two to optimal guard interval length detector 123.

[0121] Thus, the OFDM transmission/reception apparatus of the present embodiment uses a known symbol as the optimal guard interval length detection signal, therefore can improve the accuracy of the optimal guard interval length selection control signal.

(Embodiment 8)

[0122] The OFDM transmission/reception apparatus of Embodiment 8 of the present invention has the same configuration as that of the OFDM transmission/reception apparatus of Embodiment 1 and uses a variable threshold to be used in the optimal guard interval length detector.

[0123] The OFDM transmission/reception apparatus of the present embodiment is explained below using FIG.17. FIG.17 is a block diagram showing an outlined configuration of the optimal guard interval length detector of the OFDM transmission/reception apparatus of Embodiment 8 of the present invention. The parts with the same configuration as that of Embodiment 1 are assigned the same numbers and their detailed explanations are omitted.

[0124] Switch 1301 selects an input decision error and outputs it to S/P converter 402 and Averager 1302. The previous burst channel quality information is stored in memory 1304 by the switching of switch 1303.

[0125] The channel quality information stored in memory 1304 is subjected to a subtraction with threshold A by subtractor 1305. Decider 1306 decides which is larger/smaller based on the subtraction result. Switch 1307 is controlled by the decision result of Decider 1306 and outputs either threshold B or threshold C. Here, suppose threshold B > threshold C.

[0126] As shown above, considering the possibility that if, for example, the channel quality is bad, variations in the

FIG.20 is a block diagram showing an outlined configuration of the OFDM transmission/reception apparatus of Embodiment 11 of the present invention. The parts with the same configuration as that of Embodiment 1 are assigned the same numbers and their detailed explanations are omitted.

[0139] The present embodiment describes a case where a radio communication is carried out using a OFDM/TDD system.

[0140] In FIG.20, optimal guard interval length detector 1601 outputs a control signal about the guard interval length to guard interval inserter 105.

[0141] In a TDD system, a same frequency is used for the uplink and downlink, and therefore the channel information is identical for the uplink and downlink. Therefore, the OFDM transmission/reception apparatus of the present embodiment can eliminate the need for transmission/reception of the optimal guard interval length selection control signal by transmitting a signal using the optimal guard interval length detected from the reception signal in both radio stations carrying out a radio communication.

[0142] In the case that the OFDM transmission/reception apparatus of the present embodiment uses the optimal guard interval length selection control signal, the OFDM transmission/reception apparatus of the present embodiment can also detect the optimal guard interval length even if an error exists in the optimal guard interval length selection control signal after demodulation. Thus, the OFDM transmission/reception apparatus of the present embodiment can prevent the error rate characteristic of the control signal from deteriorating.

(Embodiment 12)

[0143] The OFDM transmission/reception apparatus of Embodiment 12 of the present invention has the same configuration as that of the OFDM transmission/reception apparatus of Embodiment 11, and detects the optimal guard interval length using a control channel signal.

[0144] The OFDM transmission/reception apparatus of the present embodiment is explained below using FIG.21. FIG.21 is a block diagram showing an outlined configuration of the OFDM transmission/reception apparatus of Embodiment 12 of the present invention. The parts with the same configuration as that of Embodiment 11 are assigned the same numbers and their detailed explanations are omitted.

[0145] In FIG.21, switches 1701 and 1702 are controlled by a control channel signal whose error is corrected more strongly than the user channel signal. That is, the control channel signal controls the timing of inserting an optimal guard interval length detection signal in the transmission system and the timing of extracting an optimal guard interval length detection signal in the reception system.

[0146] As shown above, the OFDM transmission/reception apparatus of the present embodiment detects the guard interval length using a control channel signal, and therefore can reduce the probability that an error will occur in the control signal that the optimal guard interval length detector outputs.

(Embodiment 13)

[0147] The OFDM transmission/reception apparatus of Embodiment 13 of the present invention has the same configuration as that of the OFDM transmission/reception apparatus of Embodiment 1, and controls the selection of the guard interval length to be added to a valid symbol using a known signal (Unique Word; hereinafter referred to as "UW") to acquire synchronization of a plurality of frames.

[0148] The OFDM transmission/reception apparatus of the present embodiment is explained below using FIG.22 and FIG.23. FIG.22 is a block diagram showing an outlined configuration of the OFDM transmission/reception apparatus of Embodiment 13 of the present invention. FIG.23 is a block diagram showing an outlined configuration of a UW detector of the OFDM transmission/reception apparatus of Embodiment 13 of the present invention. The parts with the same configuration as that of Embodiment 1 are assigned the same numbers and their detailed explanations are omitted.

[0149] In FIG.22, the output of optimal guard interval length detector 123 controls switch 1801. One of UW1 to UW4 is selected by switch 1801 according to this control and output to switch 103.

[0150] Here, in the case that the decision error of UW1 is bad, UW1 indicates that a guard interval length of "symbol period/2" is necessary. Likewise, UW2 indicates that a guard interval length of "3 × symbol period/8" is necessary; UW3, guard interval length of "symbol period/4"; and UW4, guard interval length of "symbol period/8."

[0151] UW detector 1802 detects UW in the demodulated reception signal. The detected UW is selectively output to guard interval inserter 105 by switch 1803.

[0152] Generally, in frame synchronization acquisition using UW, an exclusive OR calculation between UW and a demodulated signal is performed. In the case that the accumulated value of the results of the exclusive OR calculations exceeds a threshold, it is determined that frame synchronization has been acquired. Here, even if errors exist in the UW after demodulation in the case that the number of those errors is within the range that the accumulated value of the

[0167] As shown above, the OFDM transmission/reception apparatus of the present embodiment acquires frame synchronization using coherent detected signals prior to decision processing, and thus can reduce the probability that an error will occur in a control signal.

(Embodiment 16)

[0168] The OFDM transmission/reception apparatus of Embodiment 16 of the present invention has the same configuration as that of the OFDM transmission/reception apparatus of Embodiment 13, and uses a variable threshold in UW detectors according to decision errors.

[0169] The OFDM transmission/reception apparatus of the present embodiment is explained below using FIG.27 and FIG.28. FIG.27 is a block diagram showing an outlined configuration of the OFDM transmission/reception apparatus of Embodiment 16 of the present invention. FIG.28 is a block diagram showing an outlined configuration of the UW detector of the OFDM transmission/reception apparatus of Embodiment 16 of the present invention. The parts with the same configuration as that of Embodiment 13 are assigned the same numbers and their detailed explanations are omitted.

[0170] As shown in FIG.27, the decision error of carrier 1, which is the output of subtractor 122, together with a demodulated signal is input to UW detector 2301. The decision error need not always be from carrier 1.

[0171] Furthermore, as shown in FIG.28, subtractor 2401 performs a subtraction between the decision error input to UW detector 2301 and threshold A. Then, Decider 2402 decides which is larger/smaller based on the subtraction result. Switch 2403 is controlled by the output of Decider 2402. Switch 2403 outputs threshold B in the case that the decision error is not less than the threshold and outputs threshold C in the case that the decision error is less than the threshold. Here, suppose threshold B > threshold C.

[0172] As shown above, the OFDM transmission/reception apparatus of the present embodiment uses a variable threshold used to acquire frame synchronization in the UW detectors according to the channel quality. That is, the OFDM transmission/reception apparatus of the present embodiment decreases the threshold when the channel quality is bad. This allows the OFDM transmission/reception apparatus of the present embodiment to improve the accuracy of frame synchronization acquisition. Moreover, in the case that the channel quality is bad, the OFDM transmission/reception apparatus of the present embodiment can also improve the accuracy of frame synchronization acquisition by reducing the threshold using the channel quality information of the previous burst (for example, decision error).

(Embodiment 17)

[0173] The OFDM transmission/reception apparatus of Embodiment 17 of the present invention has the same configuration as that of the OFDM transmission/reception apparatus of Embodiment 13, and in the case that the decision error in the UW detector exceeds a threshold, it controls in such a way that the guard interval length is maintained.

[0174] The OFDM transmission/reception apparatus of the present embodiment is explained below using FIG.29. FIG.29 is a block diagram showing an outlined configuration of the UW detector of the OFDM transmission/reception apparatus of Embodiment 17 of the present invention. The parts with the same configuration as that of Embodiments 13 and 16 are assigned the same numbers and their detailed explanations are omitted.

[0175] In FIG.29, switch 2501 is controlled by the output of Decider 2402. Switch 2501 selects either the output of switch 1915 or a zero value and outputs it.

[0176] As shown above, in the case that the channel quality is bad in the UW detector, the OFDM transmission/reception apparatus of the present embodiment outputs a zero value to maintain the guard interval length without changing the threshold for acquisition of frame synchronization. Therefore, the OFDM transmission/reception apparatus of the present embodiment can prevent the error rate characteristic from deteriorating or frame synchronization from failing to be acquired, a situation which is likely to occur when a threshold is changed with a bad channel quality.

(Embodiment 18)

[0177] The OFDM transmission/reception apparatus of Embodiment 18 of the present invention has the same configuration as that of the OFDM transmission/reception apparatus of Embodiment 1, and does not change the length of a guard interval to be added to a valid symbol indicating important information, but always keeps it constant independently of the channel quality.

[0178] The "guard interval length necessary to eliminate delayed signal" described so far in Embodiments 1 to 17 has been the length apparently enough to achieve an error rate in a communication related to user data such as a message (hereinafter referred to as "normal information"). However, higher accuracy is required for important information such as control information and retransmission information than normal information in terms of the error rate.

[0179] Thus, the OFDM transmission/reception apparatus of the present embodiment distinguishes important infor-

ing normal information thereby improving the transmission-efficiency, while it can set a lower error rate for important information than for normal information. Thus, the OFDM transmission/reception apparatus of the present embodiment can improve the channel quality and transmission efficiency.

(Embodiment 20)

[0191] The OFDM transmission/reception apparatus of Embodiment 20 of the present invention has the same configuration as that of the OFDM transmission/reception apparatus of Embodiment 19, and adds to the valid symbol indicating important information a guard interval longer by a predetermined value determined according to the channel quality than the guard interval to be added to the valid symbol indicating normal information.

[0192] The OFDM transmission/reception apparatus of Embodiment 19 of the present invention always adds to the valid symbol indicating important information a guard interval consisting of the guard interval added to the valid symbol indicating normal information according to the channel quality plus a predetermined constant length. Therefore, under a condition with a high error rate and poor channel quality, there may be cases where it is impossible to improve the error rate of important information by predetermined percentage compared to the error rate of normal information.

[0193] Therefore, in the guard interval length setting of the present embodiment, the OFDM transmission/reception apparatus sets the length of the guard interval to be added to the valid symbol indicating important information to the length of the guard interval to be added to the valid symbol indicating normal information according to the channel quality plus a predetermined length proportional to the channel quality.

[0194] That is, as the channel quality improves and the error rate decreases, the OFDM transmission/reception apparatus of the present embodiment shortens the predetermined value added to the length of the guard interval to be added to the valid symbol indicating normal information, and to the contrary as the channel quality deteriorates and the error rate increases, the OFDM transmission/reception apparatus of the present embodiment lengthens the predetermined value added to the length of the guard interval to be added to the valid symbol indicating normal information.

[0195] As shown above, the OFDM transmission/reception apparatus of the present embodiment distinguishes important information from normal information in the transmission signal and sets the length of the guard interval to be added to the valid symbol indicating important information longer than the guard interval to be added to the valid symbol indicating normal information by a predetermined variable length according to the channel quality. Through this, the OFDM transmission/reception apparatus of the present embodiment can change the length of a guard interval to be added to the valid symbol indicating normal information thereby improving the transmission efficiency, while it can set a lower error rate for important information than for normal information. Thus, the OFDM transmission/reception apparatus of the present embodiment can improve the channel quality and transmission efficiency.

[0196] Here, in contrast to the configuration of the OFDM transmission/reception apparatus of Embodiments 1 to 17 with a variable guard interval length, the configuration of the OFDM transmission/reception apparatus of Embodiments 18 to 20 above distinguishes important information from normal information in the transmission signal and sets the guard interval length as follows:

1) For normal information: variable according to channel quality; for important information: constant
2) For normal information: variable according to channel quality; for important information: constant difference from the one "for normal information"
3) For normal information: variable; for important information: difference from the one "for normal information" is variable according to channel quality

[0197] These are intended to keep the error rate of important information lower than the error rate of normal information, and the OFDM transmission/reception apparatus can take any configuration other than the above 3 configurations so long as it can achieve these purposes.

[0198] Embodiments 18 to 20 above are Embodiment 1 with the additional function to improve the error rate about important information. In like manner, it is also possible to add the additional function to improve the error rate about important information to Embodiments 2 to 17 by combining Embodiments 18 to 20 above with Embodiments 2 to 17.

[0199] Embodiments 18 to 20 above can improve the error rate not only about important information but also about specific information and packet (burst). Embodiments 18 to 20 above can have a longer guard interval than other information or packet (burst) in the case of multicast, for example.

[0200] As explained above, the present invention is capable of improving transmission efficiency while maintaining the function of adding guard intervals and eliminating delayed signals.

[0201] The present invention is not limited to the above described embodiments, and various variations and modifications may be possible without departing from the scope of the present invention.

[0202] This application is based on the Japanese Patent Application No.HEI 10-365430 filed on December 22, 1998 and the Japanese Patent Application No.HEI 11-074621 filed on March 18, 1999, entire content of which is

said generator calculates a logical product of the output of said symbol extractor and every decision error of the symbol indicating the same guard interval length of each carrier.

8. The OFDM transmission/reception apparatus according to claim 6, wherein said first extractor does not extract guard interval length detection signals inserted into carriers whose reception level is not less than a threshold.

9. The OFDM transmission/reception apparatus according to claim 2, wherein said first inserter inserts a guard interval length detection signal comprising a known symbol, and

said first extractor calculates the difference between the known symbol inserted by said first inserter and the known symbol in the reception signal after coherent detection and outputs the difference to said generator.

10. The OFDM transmission/reception apparatus according to claim 4, wherein said symbol extractor in said generator uses a first threshold in the case that the decision error of the guard interval length detection signal extracted by said first extractor is not less than a predetermined constant value and uses a second threshold, which is smaller than the first threshold in the case that the decision error of the guard interval length detection signal extracted by said first extractor is less than the predetermined constant value.

11. The OFDM transmission/reception apparatus according to claim 4, wherein said generator comprising:

a counter(1401-1403) that converts the output of said symbol extractor to a data signal per a predetermined time; and
a signal extractor(1404-1409) that extracts signals including the symbol indicating the shortest guard interval length from among signals whose counter output is less than the threshold.

12. The OFDM transmission/reception apparatus according to claim 2, wherein said generator generates a guard interval length selection control signal so as to set the longest guard interval in the case that the reception level of the carrier into which the optimal guard interval length selection control signal detected by said second inserter is inserted falls below the threshold.

13. An OFDM/TDD transmission/reception apparatus comprising:

a guard interval inserter(105) that inserts part of a valid symbol at the start of the valid symbol of a transmission signal as a guard interval;
a guard interval length regulator(201-206) that extends/contracts the guard interval length that the guard interval inserter inserts into a transmission signal;
an inserter(102) that inserts a guard interval length detection signal comprising a plurality of symbols indicating different guard interval lengths into one carrier of said transmission signal;
an extractor(117,122) that extracts the decision error of a guard interval length detection signal from among the reception signals using the same frequency as that of the transmission signal; and
a guard interval length controller that controls said guard interval length regulator based on the output of the extractor.

14. The OFDM/TDD transmission/reception apparatus according to claim 13, wherein said apparatus controls insertion timing of said inserter and extraction timing of said extractor by control channel signals.

15. An OFDM transmission/reception apparatus comprising:

a guard interval inserter(105) that inserts part of a valid symbol at the start of the valid symbol of a transmission signal as a guard interval;
a guard interval length regulator(201-206) that extends/contracts the guard interval length that the guard interval inserter inserts into the transmission signal;
a first inserter(102) that inserts a guard interval length detection signal into one carrier of the transmission signal;
a second inserter(103) that inserts a plurality of frame synchronization acquisition known signals indicating different guard interval lengths into one carrier of the transmission signal;
a first extractor(117,122,123) that extracts the decision error of a guard interval length detection signal from the reception signal;

according to the channel quality plus a variable value according to the channel quality for the valid symbol indicating important information in the transmission signal.

25. A communication terminal apparatus having an OFDM transmission/reception apparatus, said OFDM transmission/reception apparatus comprising:

a guard interval inserter(105) that inserts part of a valid symbol at the start of the valid symbol of a transmission signal as a guard interval;
a guard interval length regulator(201-206) that extends/contracts the guard interval length that the guard interval inserter inserts into the transmission signal;
a first inserter(102) that inserts a guard interval length detection signal comprising a plurality of symbols indicating different guard interval lengths into one carrier of said transmission signal; and
a second inserter(103) that inserts a guard interval length selection control signal into one carrier of said transmission signal.

26. A base station apparatus having an OFDM transmission/reception apparatus, said OFDM transmission/reception apparatus comprising:

a guard interval inserter(105) that inserts part of a valid symbol at the start of the valid symbol of a transmission signal as a guard interval;
a guard interval length regulator(201-206) that extends/contracts the guard interval length that the guard interval inserter inserts into the transmission signal;
a first inserter(102) that inserts a guard interval length detection signal comprising a plurality of symbols indicating different guard interval lengths into one carrier of said transmission signal; and
a second inserter(103) that inserts a guard interval length selection control signal into one carrier of said transmission signal.

27. An OFDM transmission/reception method comprising:

the guard interval inserting step of inserting part of a valid symbol at the start of the valid symbol of a transmission signal as a guard interval;
the guard interval length regulating step of extending/contracting the guard interval length that the guard interval inserting step inserts into the transmission signal;
the first inserting step of inserting a guard interval length detection signal comprising a plurality of symbols indicating different guard interval lengths into one carrier of said transmission signal; and
the second inserting step of inserting a guard interval length selection control signal into one carrier of said transmission signal.

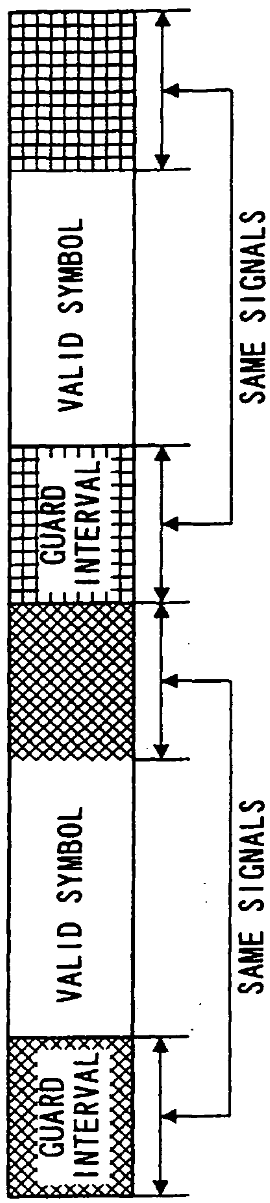

GUARD INTERVAL
VALID SYMBOL
GUARD INTERVAL
VALID SYMBOL
SAME SIGNALS
SAME SIGNALS

FIG. 3

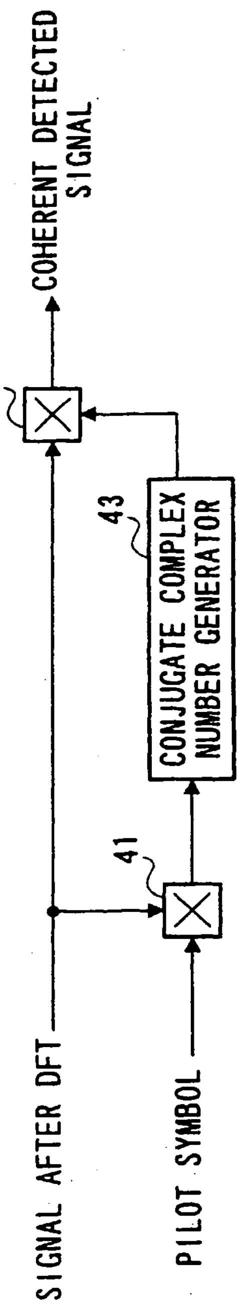

SIGNAL AFTER DFT
PILOT SYMBOL
41
43
CONJUGATE COMPLEX NUMBER GENERATOR
42
COHERENT DETECTED SIGNAL

FIG. 4

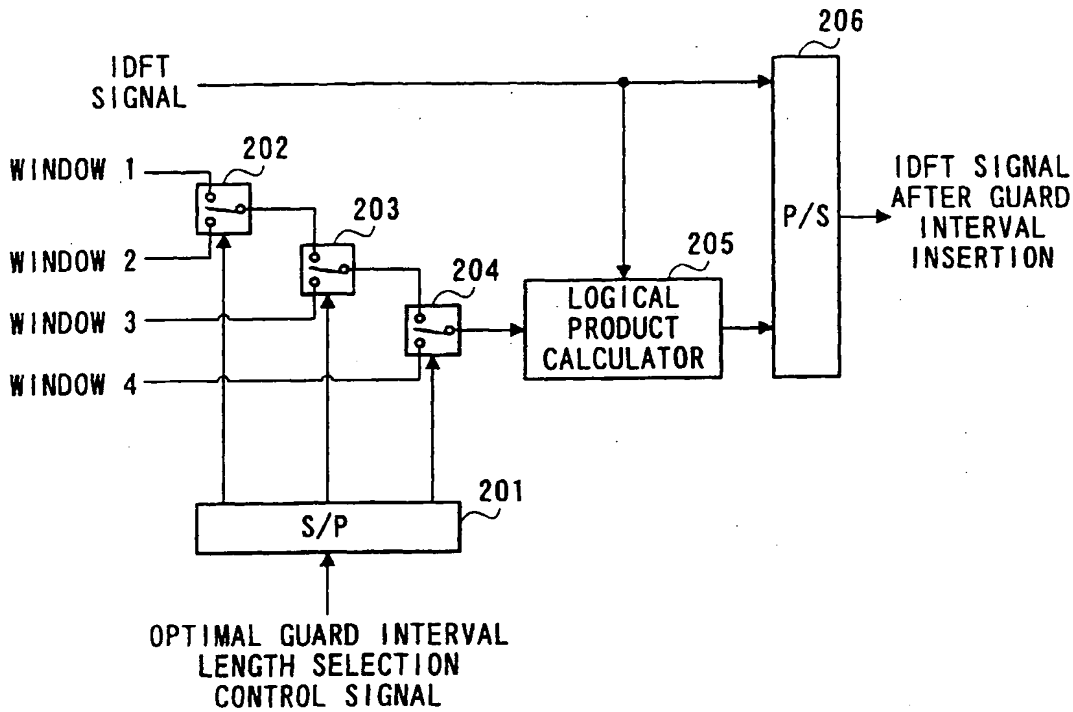

IDFT SIGNAL
WINDOW 1
WINDOW 2
WINDOW 3
WINDOW 4
202
203
204
205
206
201
LOGICAL PRODUCT CALCULATOR
P/S
S/P
IDFT SIGNAL AFTER GUARD INTERVAL INSERTION
OPTIMAL GUARD INTERVAL LENGTH SELECTION CONTROL SIGNAL

FIG. 6

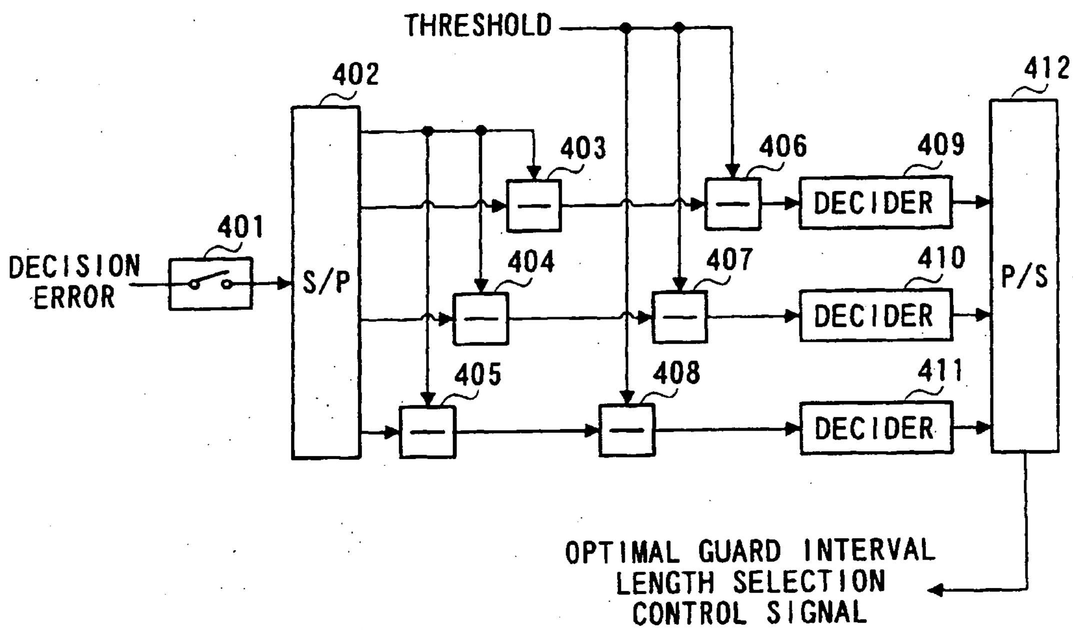

THRESHOLD
402
412
403
406
409
401
DECISION ERROR
S/P
404
407
410
P/S
DECIDER
DECIDER
405
408
411
DECIDER
OPTIMAL GUARD INTERVAL LENGTH SELECTION CONTROL SIGNAL

FIG. 8

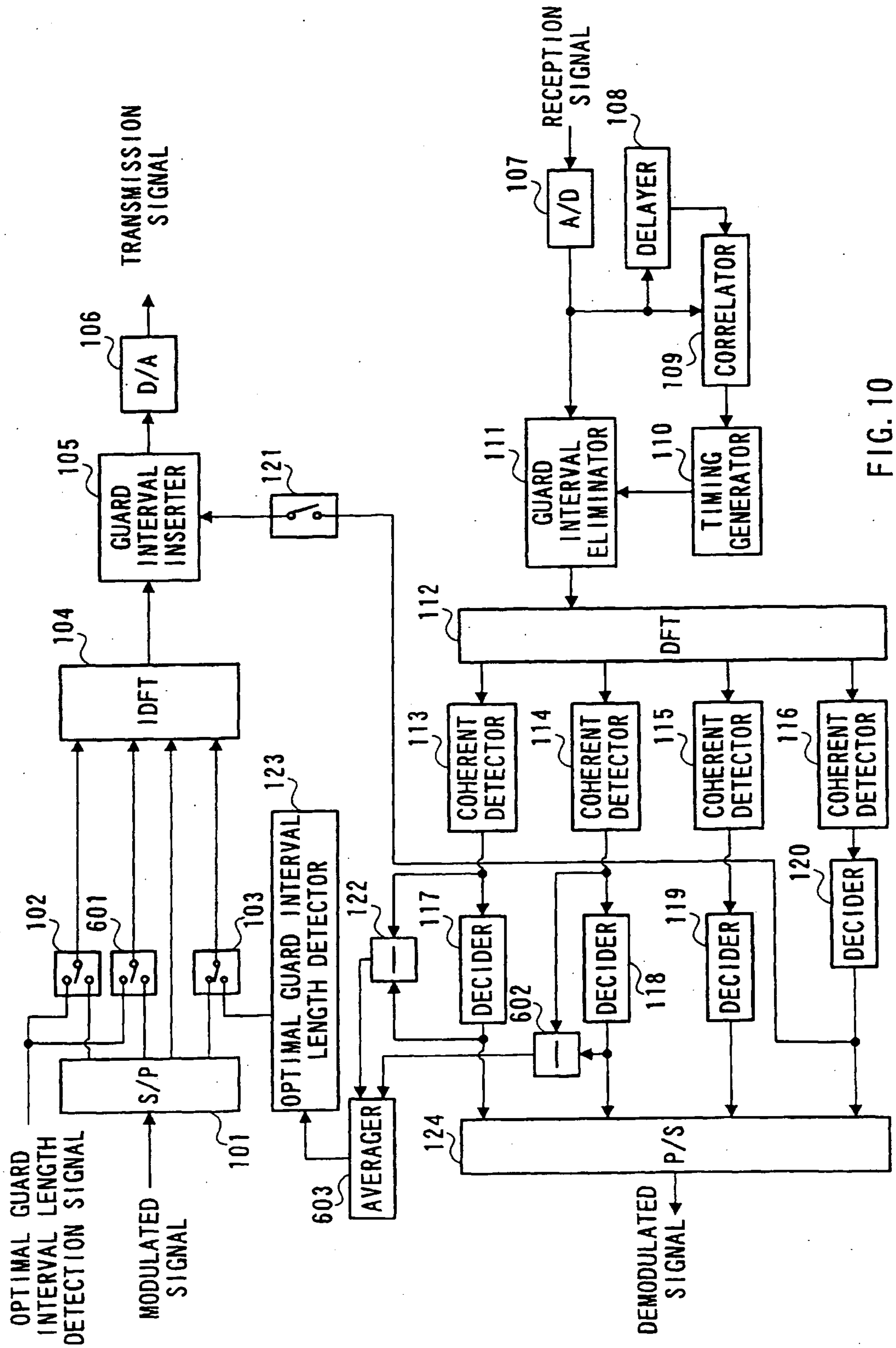

TRANSMISSION SIGNAL
106
D/A
105
GUARD INTERVAL INSERTER
121
104
IDFT
102
601
103
123
OPTIMAL GUARD INTERVAL LENGTH DETECTOR
S/P
101
OPTIMAL GUARD INTERVAL LENGTH DETECTION SIGNAL
MODULATED SIGNAL
122
603
AVERAGER
602
RECEPTION SIGNAL
107
A/D
108
DELAYER
CORRELATOR
109
110
TIMING GENERATOR
111
GUARD INTERVAL ELIMINATOR
112
DFT
113
COHERENT DETECTOR
114
COHERENT DETECTOR
115
COHERENT DETECTOR
116
COHERENT DETECTOR
117
DECIDER
118
DECIDER
119
DECIDER
120
DECIDER
124
P/S
DEMODULATED SIGNAL

FIG. 10

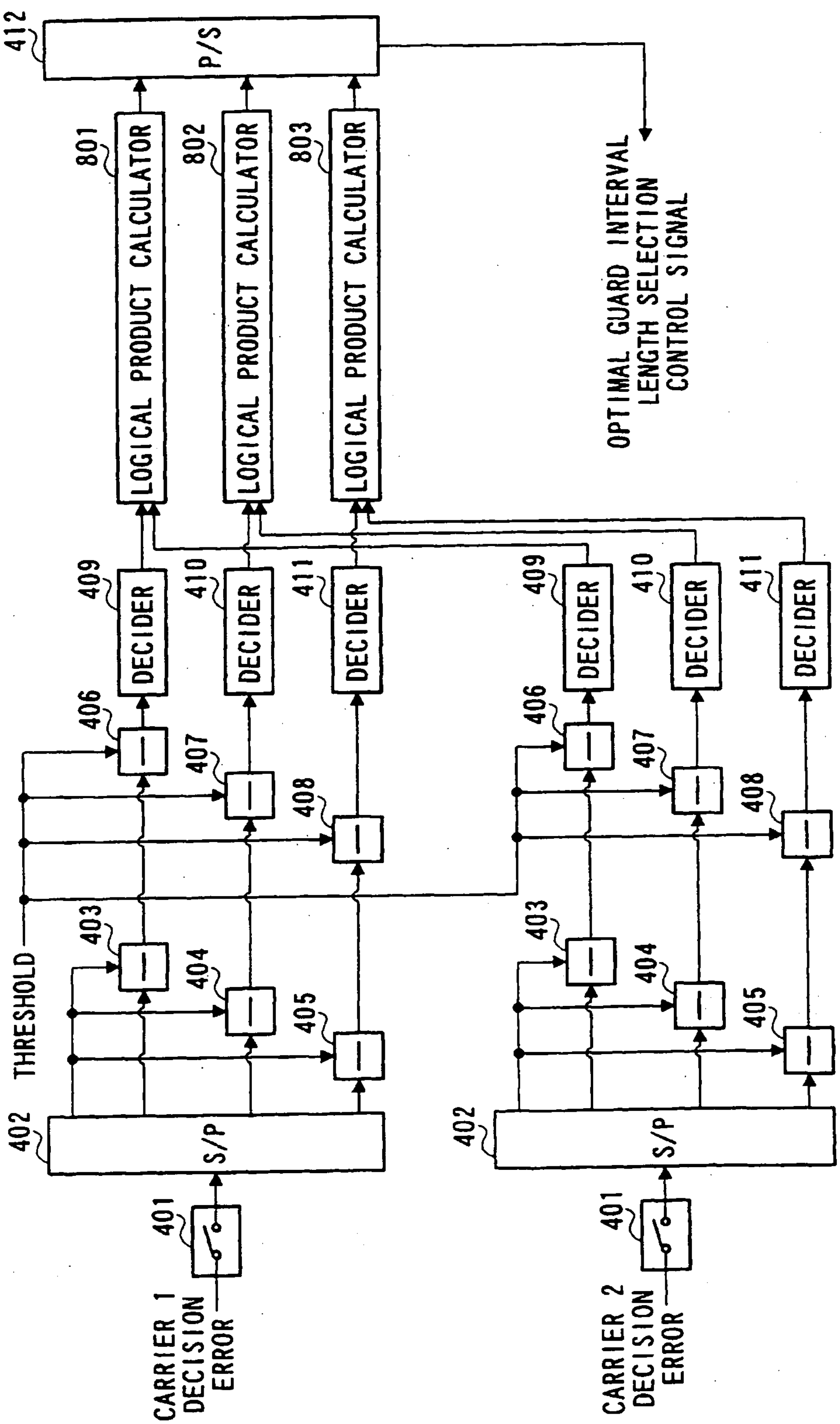

CARRIER 1 DECISION ERROR
401
402
S/P
THRESHOLD
403
404
405
406
407
408
409
DECIDER
410
DECIDER
411
DECIDER
801
LOGICAL PRODUCT CALCULATOR
802
LOGICAL PRODUCT CALCULATOR
803
LOGICAL PRODUCT CALCULATOR
412
P/S
OPTIMAL GUARD INTERVAL LENGTH SELECTION CONTROL SIGNAL
CARRIER 2 DECISION ERROR
401
402
S/P
403
404
405
406
407
408
409
DECIDER
410
DECIDER
411
DECIDER

FIG. 12

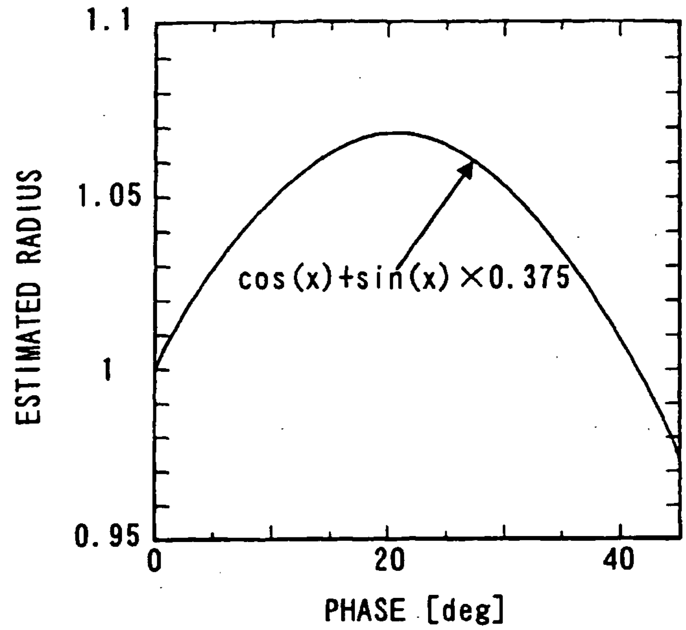

1.1
1.05
1
0.95
ESTIMATED RADIUS
cos(x)+sin(x)×0.375
0
20
40
PHASE [deg]

FIG. 14

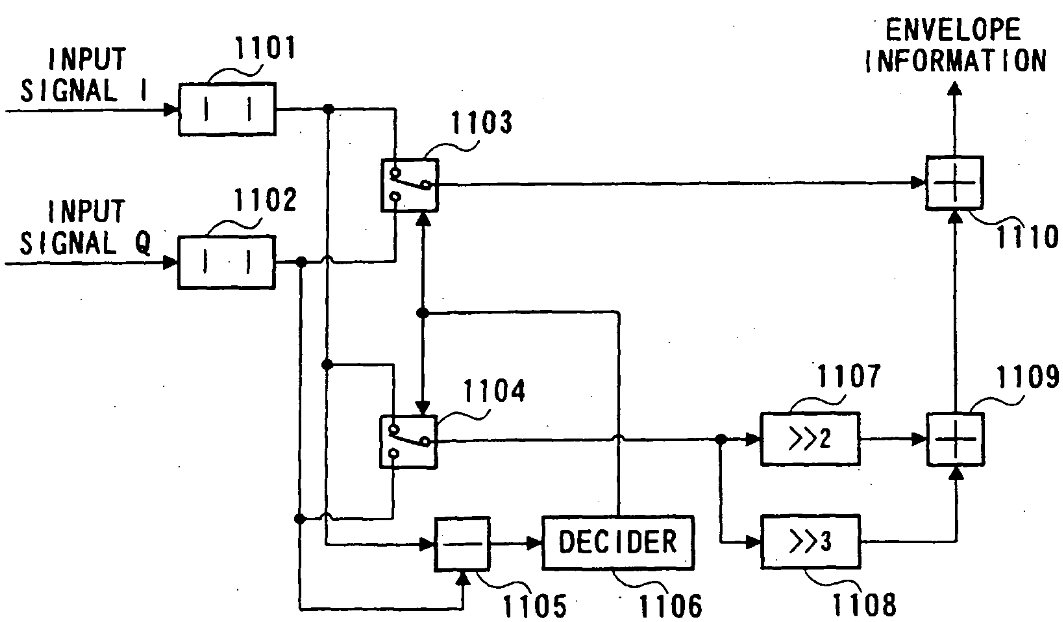
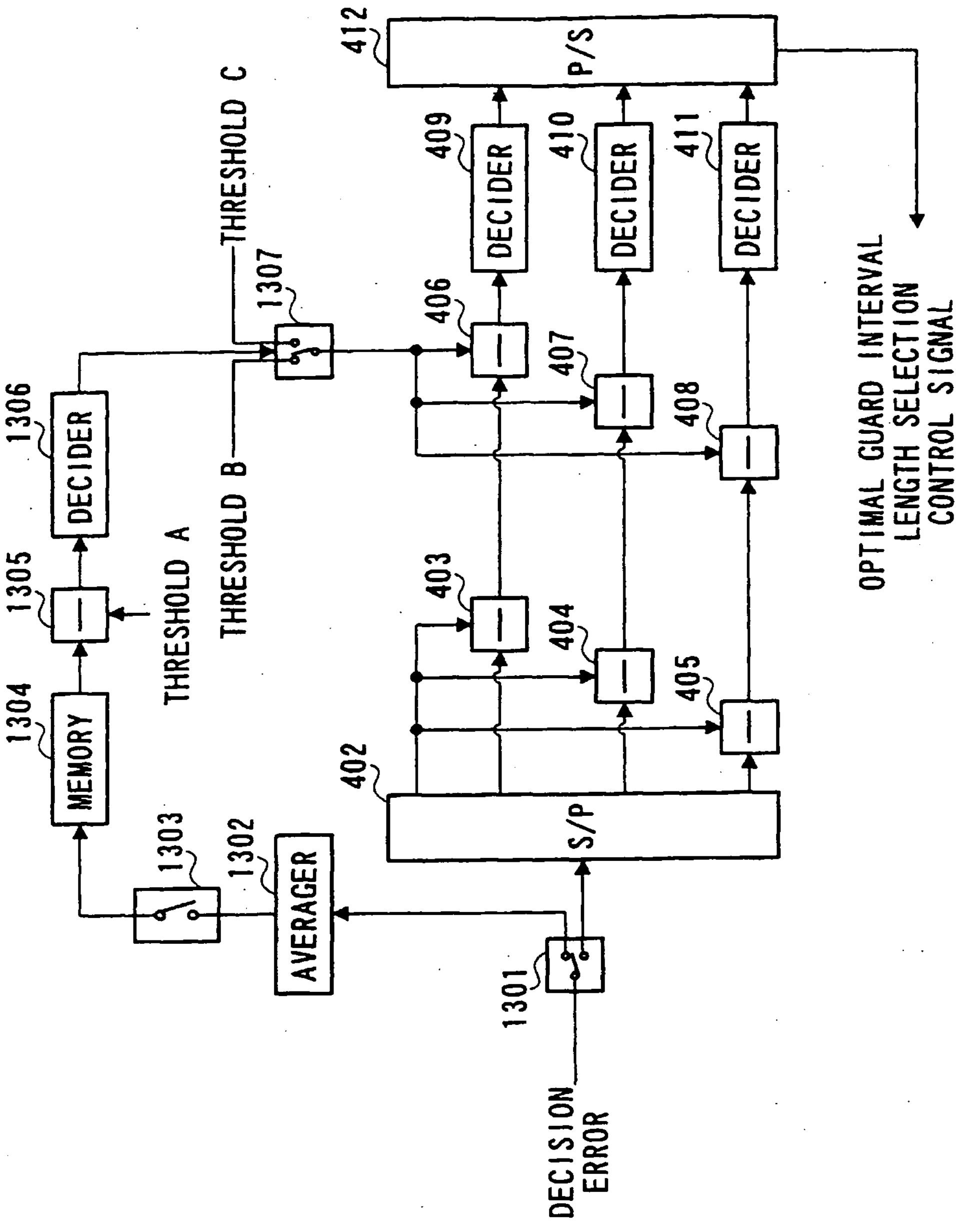

INPUT SIGNAL I
INPUT SIGNAL Q
1101
1102
1103
1104
1105
DECIDER
1106
>>2
1107
>>3
1108
1109
1110
ENVELOPE INFORMATION

FIG. 15



412
P/S
409
DECIDER
410
DECIDER
411
DECIDER
THRESHOLD C
1307
406
407
408
1306
DECIDER
1305
1304
MEMORY
THRESHOLD A
THRESHOLD B
403
404
405
402
S/P
1303
1302
AVERAGER
1301
DECISION ERROR
OPTIMAL GUARD INTERVAL LENGTH SELECTION CONTROL SIGNAL

FIG. 17

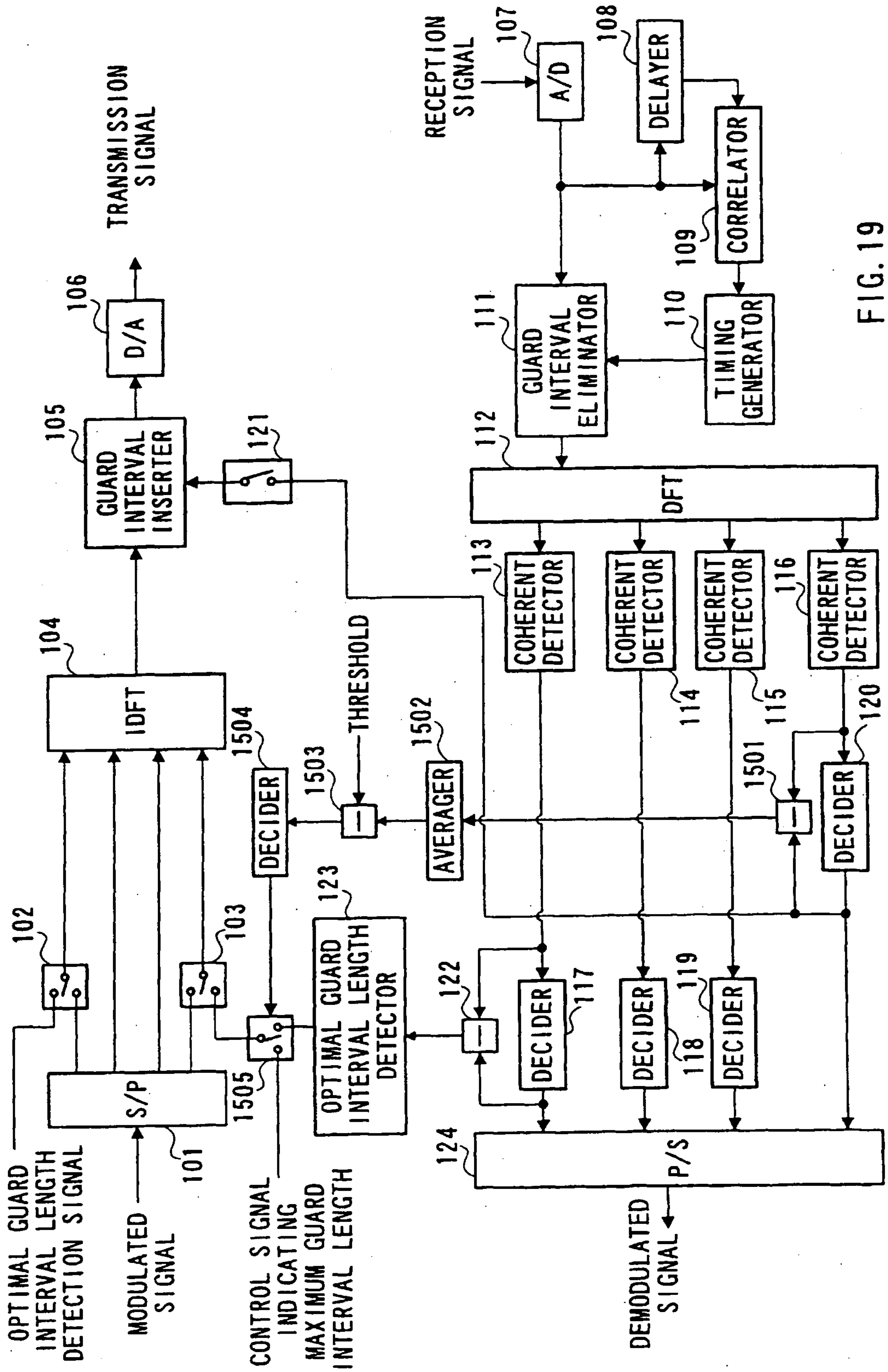

TRANSMISSION SIGNAL
106
D/A
105
GUARD INTERVAL INSERTER
121
104
IDFT
THRESHOLD
1504
DECIDER
1503
—
1502
AVERAGER
102
103
OPTIMAL GUARD INTERVAL LENGTH DETECTION SIGNAL
S/P
101
MODULATED SIGNAL
1505
CONTROL SIGNAL INDICATING MAXIMUM GUARD INTERVAL LENGTH
123
OPTIMAL GUARD INTERVAL LENGTH DETECTOR
122
—
RECEPTION SIGNAL
107
A/D
108
DELAYER
109
CORRELATOR
110
TIMING GENERATOR
111
GUARD INTERVAL ELIMINATOR
112
DFT
113
COHERENT DETECTOR
114
COHERENT DETECTOR
115
COHERENT DETECTOR
116
COHERENT DETECTOR
120
1501
—
DECIDER
117
DECIDER
118
DECIDER
119
DECIDER
124
P/S
DEMODULATED SIGNAL

FIG. 19

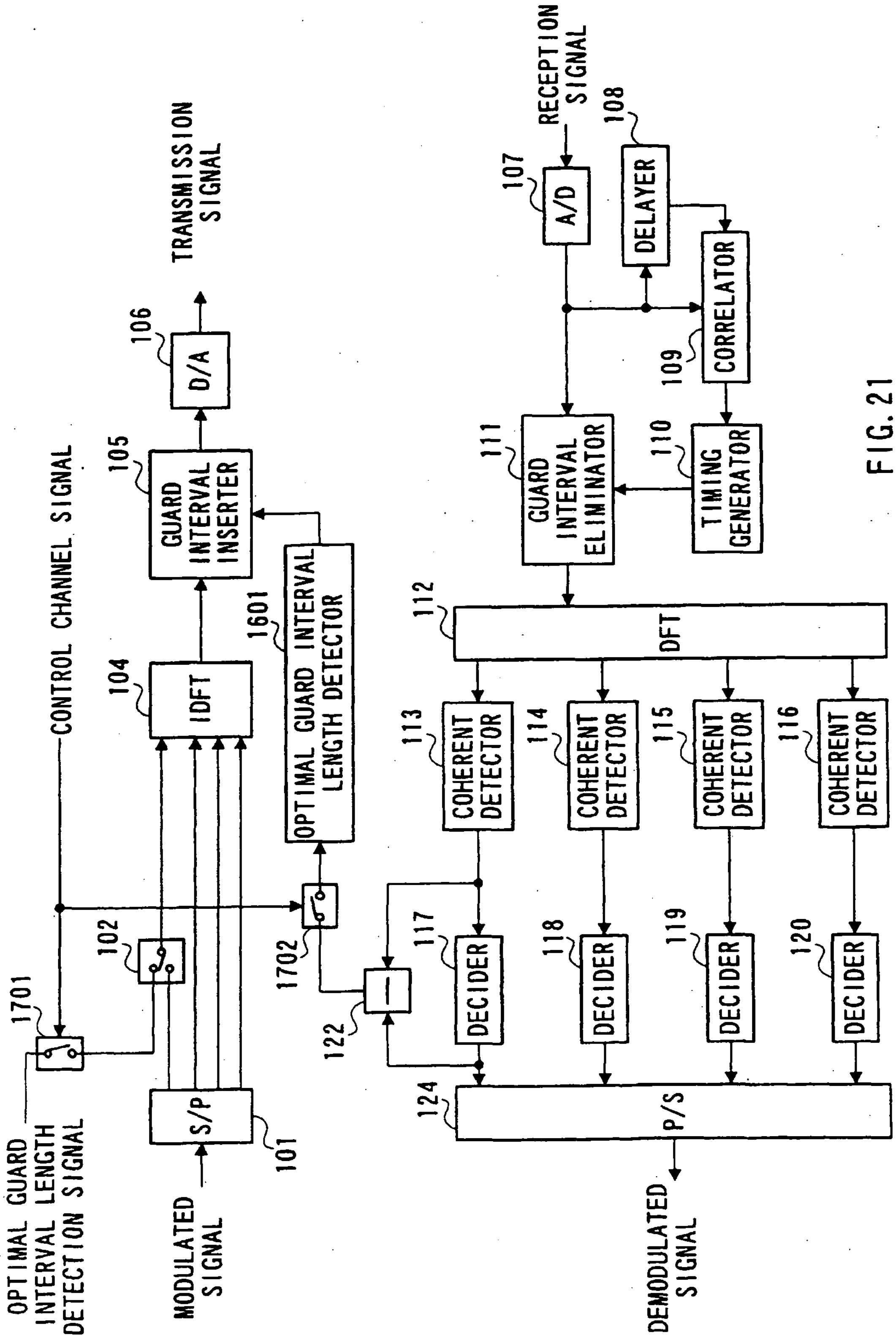

CONTROL CHANNEL SIGNAL
OPTIMAL GUARD INTERVAL LENGTH DETECTION SIGNAL
1701
102
MODULATED SIGNAL
S/P
101
104
IDFT
105
GUARD INTERVAL INSERTER
106
D/A
TRANSMISSION SIGNAL
1601
OPTIMAL GUARD INTERVAL LENGTH DETECTOR
1702
122
RECEPTION SIGNAL
107
A/D
108
DELAYER
109
CORRELATOR
110
TIMING GENERATOR
111
GUARD INTERVAL ELIMINATOR
112
DFT
113
114
115
116
COHERENT DETECTOR
117
118
119
120
DECIDER
124
P/S
DEMODULATED SIGNAL

FIG. 21

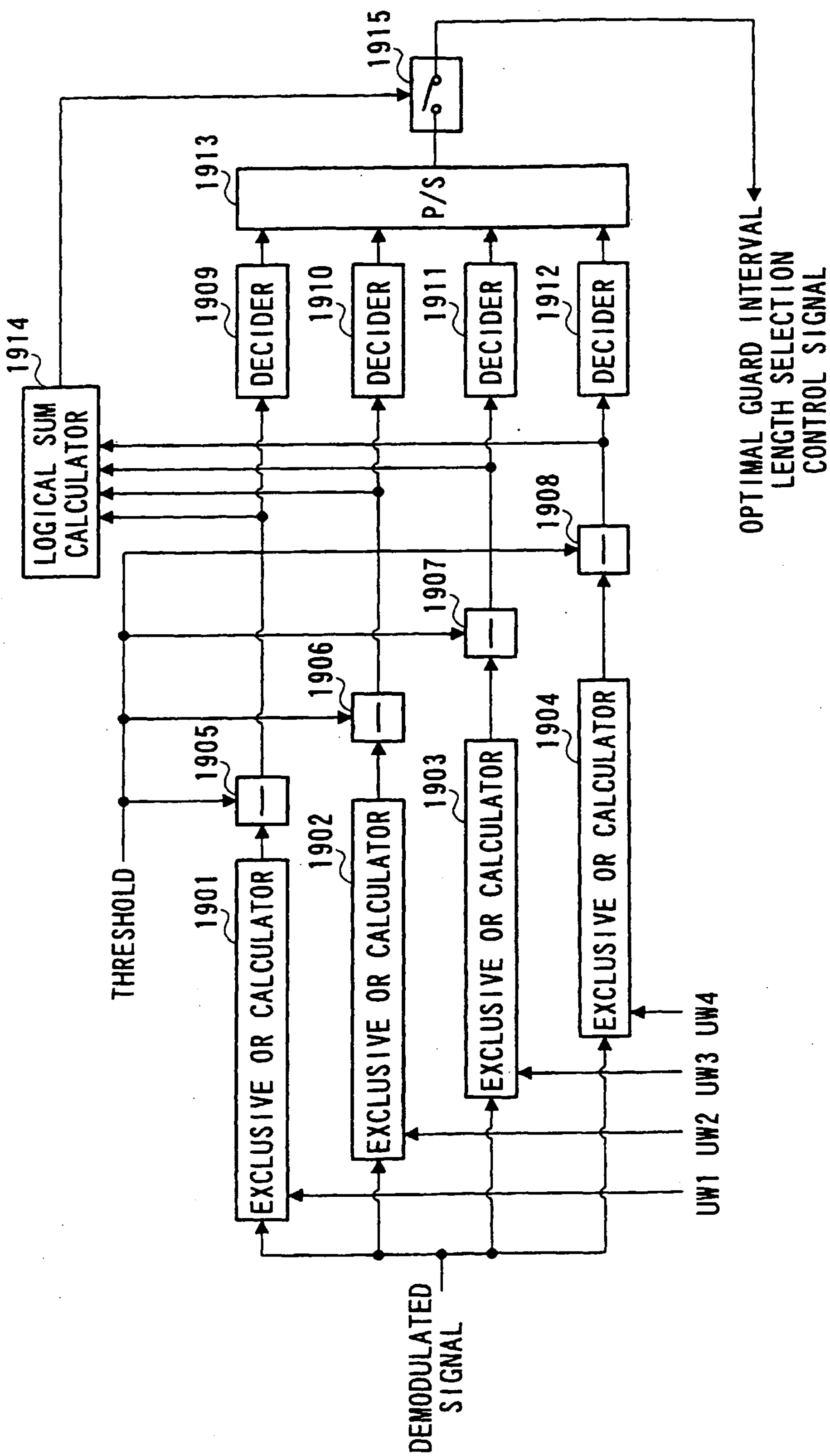

1915
1913
P/S
1914
LOGICAL SUM CALCULATOR
1909
DECIDER
1910
DECIDER
1911
DECIDER
1912
DECIDER
1908
1907
1906
1905
THRESHOLD
1901
EXCLUSIVE OR CALCULATOR
1902
EXCLUSIVE OR CALCULATOR
1903
EXCLUSIVE OR CALCULATOR
1904
EXCLUSIVE OR CALCULATOR
UW1 UW2 UW3 UW4
DEMODULATED SIGNAL
OPTIMAL GUARD INTERVAL LENGTH SELECTION CONTROL SIGNAL

FIG. 23

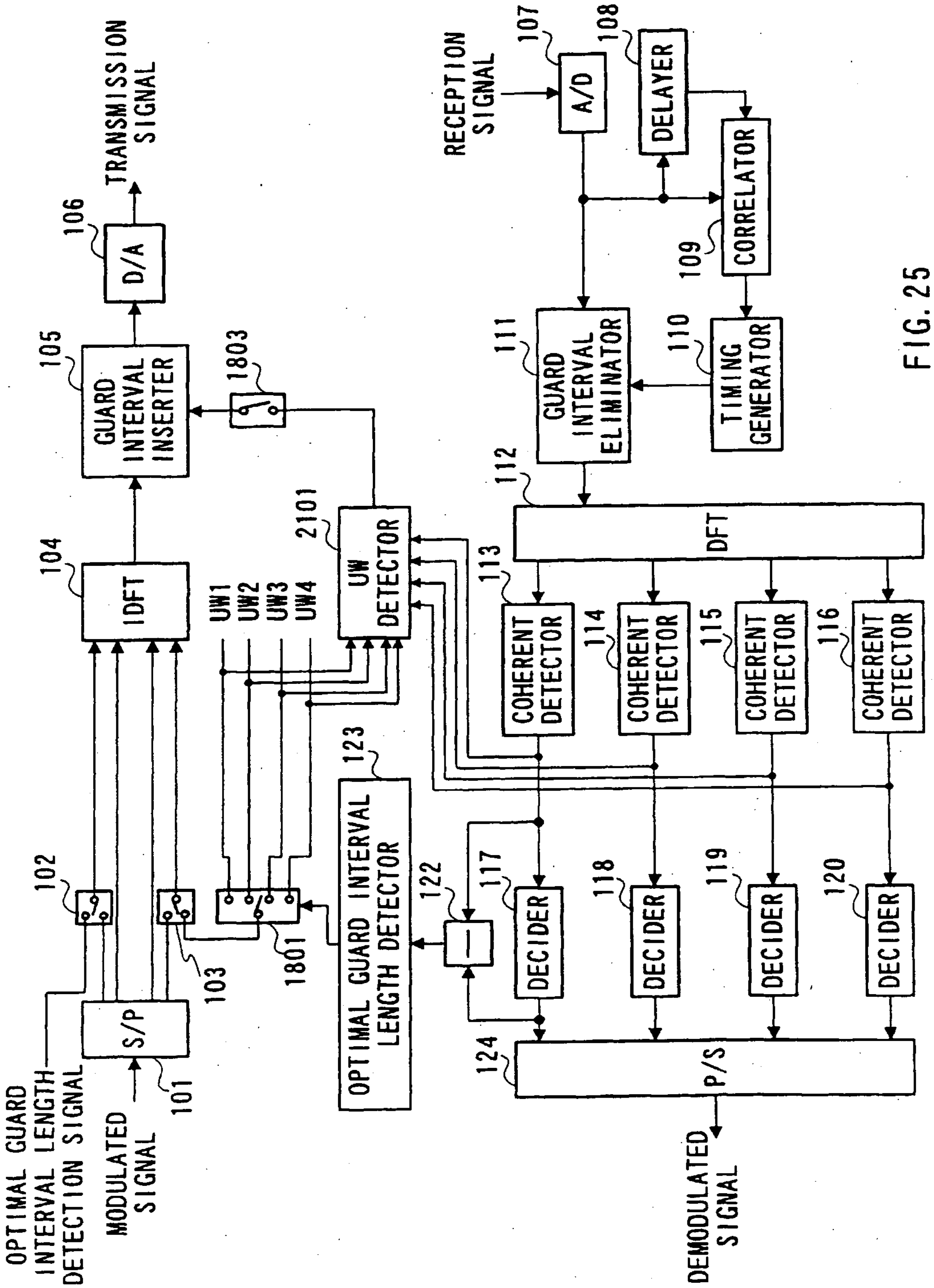

OPTIMAL GUARD INTERVAL LENGTH DETECTION SIGNAL
MODULATED SIGNAL
101
S/P
102
103
104
IDFT
105
GUARD INTERVAL INSERTER
106
D/A
TRANSMISSION SIGNAL
1803
2101
UW DETECTOR
UW1
UW2
UW3
UW4
1801
123
OPTIMAL GUARD INTERVAL LENGTH DETECTOR
122
RECEPTION SIGNAL
107
A/D
108
DELAYER
109
CORRELATOR
110
TIMING GENERATOR
111
GUARD INTERVAL ELIMINATOR
112
DFT
113
114
115
116
COHERENT DETECTOR
117
118
119
120
DECIDER
124
P/S
DEMODULATED SIGNAL

FIG. 25

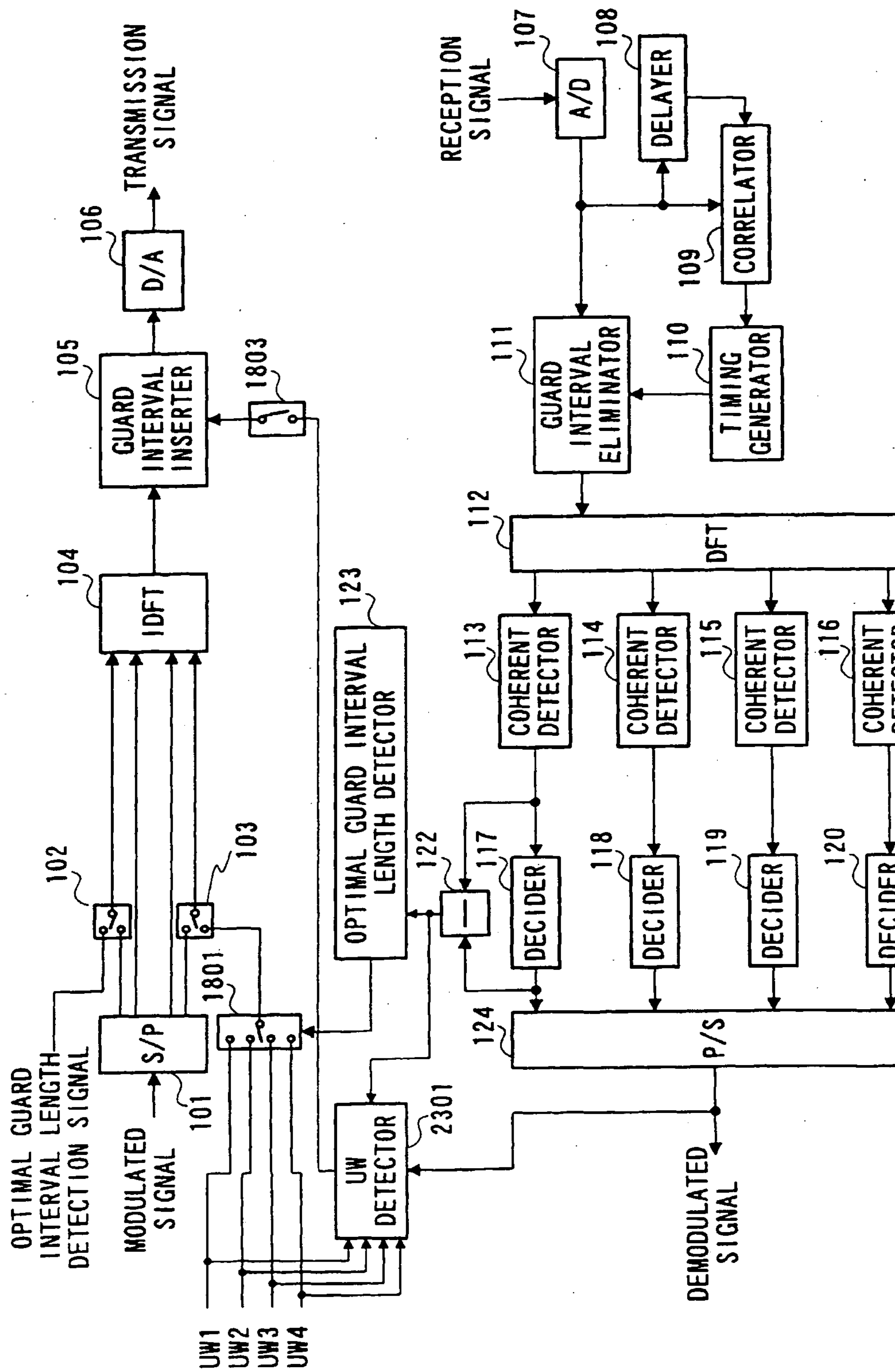

OPTIMAL GUARD INTERVAL LENGTH DETECTION SIGNAL
MODULATED SIGNAL
101
S/P
102
103
104
IDFT
105
GUARD INTERVAL INSERTER
106
D/A
TRANSMISSION SIGNAL
1801
1803
123
OPTIMAL GUARD INTERVAL LENGTH DETECTOR
2301
UW DETECTOR
UW1
UW2
UW3
UW4
RECEPTION SIGNAL
107
A/D
108
DELAYER
109
CORRELATOR
110
TIMING GENERATOR
111
GUARD INTERVAL ELIMINATOR
112
DFT
113
114
115
116
COHERENT DETECTOR
COHERENT DETECTOR
COHERENT DETECTOR
COHERENT DETECTOR
122
117
118
119
120
DECIDER
DECIDER
DECIDER
DECIDER
124
P/S
DEMODULATED SIGNAL

FIG. 27

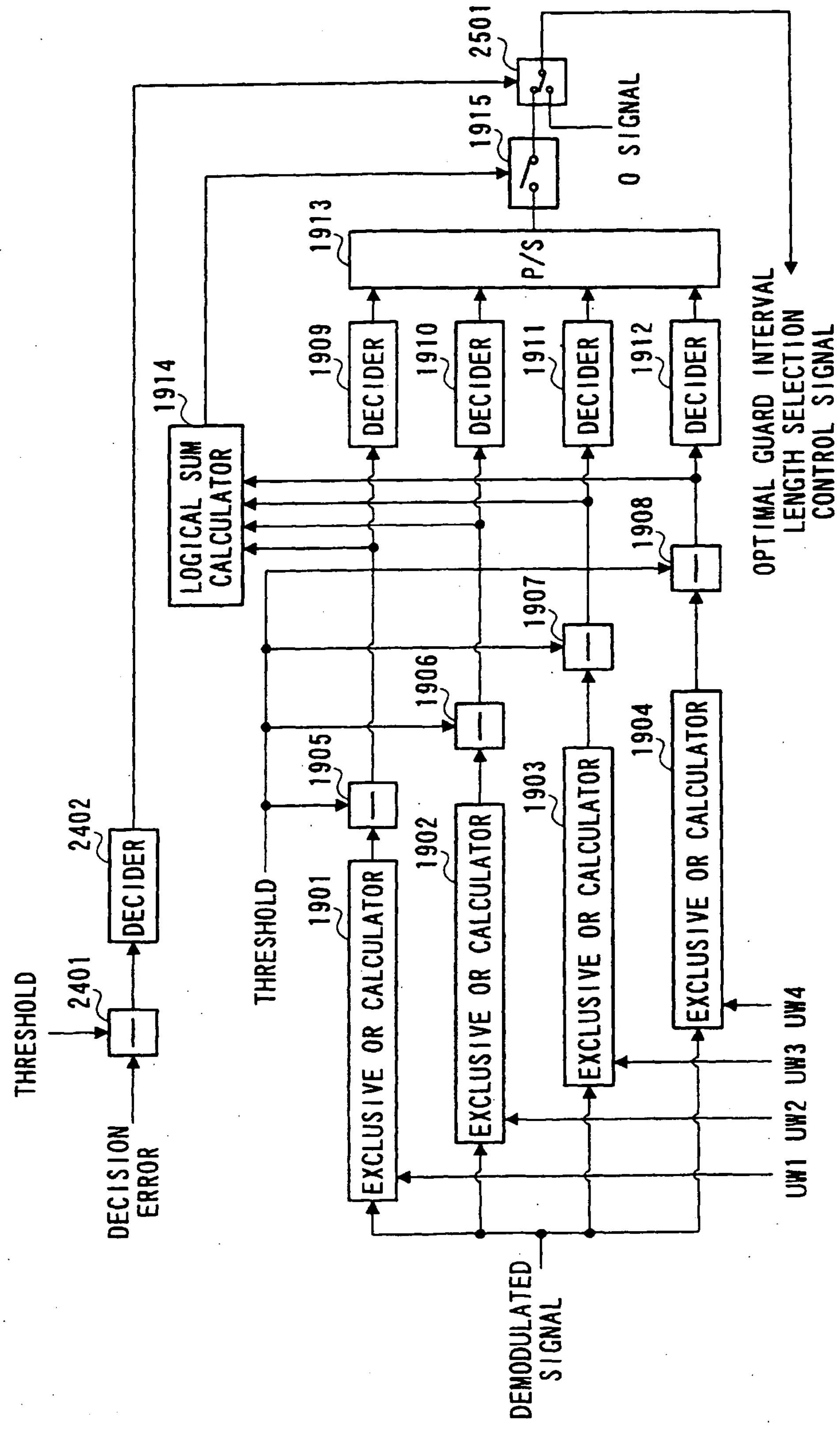
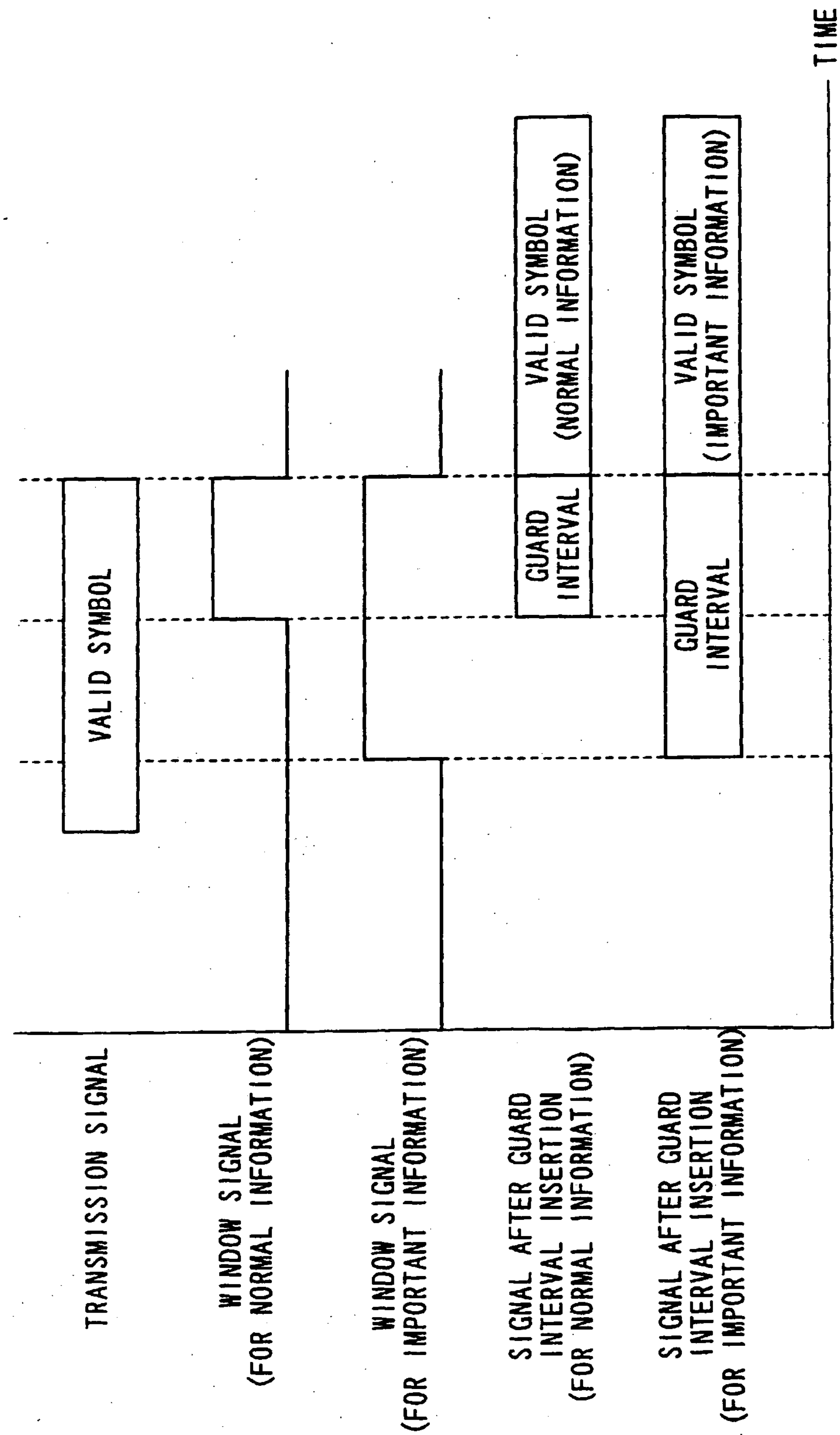

DECISION ERROR
THRESHOLD
2401
2402
DECIDER
THRESHOLD
DEMODULATED SIGNAL
UW1 UW2 UW3 UW4
1901
EXCLUSIVE OR CALCULATOR
1902
EXCLUSIVE OR CALCULATOR
1903
EXCLUSIVE OR CALCULATOR
1904
EXCLUSIVE OR CALCULATOR
1905
1906
1907
1908
1914
LOGICAL SUM CALCULATOR
1909
DECIDER
1910
DECIDER
1911
DECIDER
1912
DECIDER
1913
P/S
1915
2501
0 SIGNAL
OPTIMAL GUARD INTERVAL LENGTH SELECTION CONTROL SIGNAL

FIG. 29



TRANSMISSION SIGNAL
WINDOW SIGNAL (FOR NORMAL INFORMATION)
WINDOW SIGNAL (FOR IMPORTANT INFORMATION)
SIGNAL AFTER GUARD INTERVAL INSERTION (FOR NORMAL INFORMATION)
SIGNAL AFTER GUARD INTERVAL INSERTION (FOR IMPORTANT INFORMATION)
VALID SYMBOL
GUARD INTERVAL
VALID SYMBOL (NORMAL INFORMATION)
GUARD INTERVAL
VALID SYMBOL (IMPORTANT INFORMATION)
TIME

FIG. 31